DISTRIBUTION OF SHORE BUGS AND SHORE FLIES AT SYLVAN SPRINGS, YELLOWSTONE NATIONAL PARK

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Abstract.— Three species of shore bugs (Hemiptera: Saldidae) and 10 species of brine flies (Diptera: Ephydridae) were collected at Sylvan Springs (Wyoming section of Yellowstone National Park, USA), an area containing both acid and alkaline thermal springs. The fauna consists of both widespread (e.g., shore bugs *Saldula comatula* Parshley and *Saldula explanata* [Uhler] and shore flies *Atissa litoralis* [Cole] and *Scatella stagnalis* [Fallén]) and Yellowstone Park-endemic species (e.g., *Saldula* nr. *arenicola* and the shore fly *Ephydra thermophila* Cresson). The ratio of adults to nymphs of the numerically dominant shore bug *Saldula* nr. *arenicola* is higher along heated margins (11–12:1) than along near-ambient-temperature margins (0.6–2:1) of a thermal channel at Sylvan Springs; this may reflect differences in food availability, osmoregularity, thermal tolerance, predation, or other factors. Shore flies include species typical of acid (*E. thermophila*) and alkaline (*Paracoenia bisetosa* [Coquillett] and *Paracoenia turbida* [Curran]) springs.

The insect fauna of thermal springs has been of interest to biologists worldwide (Tuxen 1944, Winterbourn 1968), but most attention in North America has been focused on the inhabitants of thermal areas in Yellowstone National Park (Montana, Idaho, but mainly Wyoming, USA). Early studies by Brues (1924, 1932) on the distribution of insects in Yellowstone thermal springs examined the faunal diversity of such habitats, and more recent studies such as Wiegert and Mitchell (1973), Collins (1975), and Collins et al. (1976) have shown that such habitats are useful field laboratories for examining conceptual aspects of insect ecology.

In Yellowstone Park hot springs, the distribution of at least some species of shore flies (Diptera: Ephydridae) may be related to the pH of these spring habitats (Wirth 1971). Since Sylvan Springs is an area of the Park that contains both alkaline and acid springs, the fauna was examined to determine whether insect species described as typical inhabitants of acid, alkaline, or both spring types occur in this area.

Methods

Brock (1978, Table 2.3) reported the water chemistry of 12 of the many springs that comprise Sylvan Springs. Two of these 12 springs were alkaline (pH values of 7.2 and 8.3), whereas the remaining 10 were acidic (pH of 1.8–5.3). At Sylvan Springs the green alga *Cyanidium caldarium* occurs in the outflows of acidic springs at pH<4, and it is the sole photosynthetic organism inhabiting spring outflows where temperatures are between 40 and 57 C (Brock 1978). A large mat of the green alga *Zygogonium* is also present at Sylvan Springs (Lynn and Brock 1969). Although this mat is adjacent to thermal areas, the water temperatures in the mat are close to those of ambient air.

Shore bugs (Hemiptera: Saldidae) and shore flies (Diptera: Ephydridae) were collected on 16 August 1982 from the periphery of the *Zygogonium* mat and along the margins of the main channel into which many of the springs at Sylvan Springs flow. Along this channel, which is approximately 150 m in length, water temperature ranged from below that of ambient air (which was 27 C at time of collections) up to 54 C. The area in which all collections were made is described by Brock (1978, Fig. 2.4, the lower quarter of the map); approximately 500 m^2 of habitat was sampled.

Results

Shore Bugs

Although the saldid *Micracanthia quadrimaculata* (Champion) has been reported to

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be abundant on and around the *Zygogonium* mats of Yellowstone Park acid springs (Collins 1972), we did not collect this species on this algal mat or in any other area of Sylvan Springs. Instead, the numerically dominant shore bug was an undescribed species of *Saldula*, in the *arenicola* group of this genus. This species appears to be endemic to thermal springs, and possibly to Yellowstone Park (J. T. Polhemus, unpubl. data). Since the entire *arenicola* group requires taxonomic revision (J. T. Polhemus, pers. comm.), this species will not be described here.

Two other species of shore bugs were collected at Sylvan Springs, *Saldula comatula* Parshley and *Saldula explanata* (Uhler). Both species are widely distributed throughout the western U.S. and Canada (Polhemus and Chapman 1979).

Within the Sylvan Springs area, S. nr. *arenicola* occurs on the ambient-temperature *Zygogonium* mat and along the margins of the main thermal channel. Individuals of this species that occur along the channel margins where water temperature is above 40 C die if they fall into the heated water. This species is unusually slow moving compared to most species of Saldidae, and a similar "sluggishness" has been reported for *Saldula usingeri* Polhemus from a California thermal spring (Polhemus 1967). This behavior may be an adaptation to avoid accidentally landing in lethal thermal waters.

The distribution of nymphs and adults of S. nr. *arenicola* varies along the thermal gradient of the main Sylvan Springs channel. The ratio of adults to nymphs is 11:1 where water temperature is 54 C and 12:1 at 42 C. In contrast, at temperatures of 30 C the ratio is less than 2:1, at 27 C it is 1:1, and at 24 C it is 0.6:1.

Saldula comatula and S. *explanata* did not occur along the thermal portions of the channel that were occupied by S. nr. *arenicola*. Both species were limited to the ambient temperature areas of the channel that were near the juncture of Sylvan Springs with the surrounding meadow and forest areas.

Shore Flies

Ten species of Ephydridae were collected at Sylvan Springs (Table 1). Eggs, larvae, and pupae of *E. thermophila*, the only ephydrid collected in the *Zygogonium* mat, were found in small pools of spring water; these ambient-temperature pools were approximately 1–3 cm deep and had no discernible flow. In contrast, Collins (1975) reported that high densities of *E. thermophila* eggs and larvae only occurred in the portions of a *Zygogonium* mat that were near outflows with high temperatures and concentrations of interstitial algae.

Adults of only 3 shore fly species, *E. thermophila*, *S. stagnalis*, and *A. litoralis*, occurred along the heated margins of the main channel, although all 10 shore fly species listed in Table 1 occurred along margins where water temperature was near that of ambient air. The above-named three species together comprised almost 90% of all shore flies collected (Table 1); this was, at least in part, because their distribution covered more of the areas of Sylvan Springs that we examined.

Since Sylvan Springs is used by park naturalists in their interpretive programs, the immature stages of shore flies within the thermal effluents were not quantitatively collected because such sampling would drastically alter the appearance of this habitat. However, the four benthic collections that were made indicated that far more shore fly larvae and pupae occurred in the cooler than in the heated portions of Sylvan Springs.

Discussion

The shore bug and shore fly components of the Sylvan Springs fauna consist of some species that are apparently endemic to Yellowstone Park (e.g., S. nr. *arenicola*, *E. thermophila*), and others that are more widespread in their distribution (e.g., S. *explanata*, S. *stagnalis*). The shore bug *M. quadrimaculata* that was previously reported as an inhabitant of Yellowstone Park acid springs closely resembles *Saldula* spp. in appearance and may have been misidentified in earlier studies.

The changing ratio of S. nr. *arenicola* adults to nymphs along the Sylvan Springs channel in which higher proportions of adults were found in heated areas, but higher proportions of nymphs were found in cooler areas, is similar to a pattern reported long ago by Hubbard (1892) for adults and larvae of the carabid beetle *Nebria* in Yellowstone Park hot spring effluents. Such a pattern could result from factors that favor nymphs in the cooler areas or adults in the heated areas, or factors detrimental to nymphs in the heated areas or adults in the cooler areas.

Increased numbers of nymphs along the cooler margins could result from S. nr. *arenicola* adults selectively ovipositing in areas that contain more abundant food. Collins (1972) described the saldids in these habitats as saprovores, whereas our studies with other species of *Saldula* suggest that they may be at least facultative predators of shore fly larvae. With either type of feeding though, the benthic samples that were made indicate that more potential food sources occur in the cooler areas of the main channel.

Increased numbers of adults along the heated margins could be related to osmoregulative or reproductive activities. For example, sexually active adults of *Saldula saltatoria* L. required high humidity microclimates to counter loss of body water (Lindskog 1968). At Sylvan Springs, higher humidity microclimates occur along the heated spring margins and might influence the distribution of S. nr. *arenicola* adults.

Since food resources are less abundant along the heated margins, adult shore bugs may cannibalize their conspecific nymphs, and consequently reduce the relative abundance of nymphs in these areas. Decreased numbers of nymphs along the heated margins may also reflect different thermal tolerances among nymphal and adult stages. Larvae of the beetle *Nebria* that Hubbard (1892) reported as more abundant in the cooler portions of hot spring effluents probably occur there because of the low thermal tolerance of the larvae (D. H. Cavanaugh, pers. comm.).

Finally, decreased numbers of adults along the cooler margins could result from selective predation by insectivorous birds, such as killdeer, *Charadrius vociferous*, that are resident to Sylvan Springs. Brock and Brock (1968)

Table 1. Adult shore flies collected at Sylvan Springs, which is in the Wyoming section of Yellowstone National Park.

Species collected	Total flies collected (%)	Distribution
Atissa litoralis (Cole)	55	Primarily east to midwest, but also in far western U.S. (Sturtevant and Wheeler 1953).
Scatella stagnalis (Fallén)	18	Nearctic and Europe (Sturtevant and Wheeler 1953).
Ephydra thermophila Cresson	14	Endemic to Yellowstone Park: Frying Pan Springs, Norris Annex Hot Springs, Nymph Creek, Sylvan Springs, Mud Volcano Springs (Wirth 1971); Sylvan Springs (Collins 1972, 1975).
Lamproscatella arichaeta Mathis	6	Mainly west of the 100th meridian, between 32° and 49° north latitude (Mathis 1979a); In Yellowstone Park: Upper Geyser Basin (collected in 1916 by A. L. Melander [Mathis 1979a]).
Scatophila sp.	4	Taxonomic difficulties in group preclude further identification of species.
Paracoenia bisetosa (Coquillett) and *Paracoenia turbida* (Curran)	1	Both species primarily in western North America (Mathis 1975); In Yellowstone Park: (localities may refer to either or both species) Lower Geyser Basin (Brock et al. 1969, Wiegert and Mitchell 1973, Collins 1977, Kuenzel and Wiegert 1977); Nez Percé Spring (Collins et al. 1976).
Scatella paludum (Meigen)	1	Holarctic; In Yellowstone Park: Sylvan Springs (Collins 1972, 1977).
Discocerina obscurella (Fallén)?	<1	Species is Holarctic, but taxonomic difficulties in group preclude positive identification of species.
Notiphila decoris Williston	<1	Mainly west of the 100th meridian, from Manitoba southward into Mexico (Mathis 1979b); In Yellowstone Park: Old Faithful, Upper Geyser Basin, West Thumb Geyser Basin, White Dome Geyser vicinity (Mathis 1979b).

noted that killdeer catch and feed on insects that occur on algal mats in cooler portions of thermal habitats. These birds may feed more heavily on the larger, more active adults of S. nr. *arenicola* than on the nymphs.

There are other possible causes of the observed pattern as well. Age-specific, diurnal, or seasonal migrations may occur in relation to this gradient, and these movements could produce such a distribution. However, additional research is needed to demonstrate which of the above, or if other, unmeasured, factors were responsible for the pattern observed.

The shore fly fauna of Sylvan Springs includes species that have been reported from either only acid (e.g., *E. thermophila*) or only alkaline (e.g., *P. bisetosa* and *P. turbida*) springs. Some confusion in the identification of these two species of *Paracoenia* in Yellowstone studies has lead to difficulties in interpreting the results of previously published research (Wirth and Mathis 1979), but both species have been reported as occurring in alkaline habitats (Wirth and Mathis 1979, Table 2). The relative abundance of acid-spring and alkaline-spring species at Sylvan Springs (e.g., *E. thermophila* 14%, *Paracoenia* spp. 1%, Table 1) reflects the pattern that acid springs are more common than alkaline springs in this habitat.

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